Why pursue the energy frontier?

A personal take

Robin Erbacher, UC Davis

BNL Snowmass EF Workshop -- April 4, 2013

Energy Frontier: personal herstory

- As a postdoc I moved from spin structure functions to energy frontier physics... never looked back.

Energy Frontier: personal herstory

- As a postdoc I moved from spin structure functions to energy frontier physics... never looked back.

- To me, the story is compelling and has kept my interest in the field alive:

Energy Frontier: personal herstory

- As a postdoc I moved from spin structure functions to energy frontier physics... never looked back.
- To me, the story is compelling and has kept my interest in the field alive:
- I've worked on and continue to work on exciting and pressing questions (in order):
  - top measurements, top searches, 4th gen, heavy T
  - top A_{fb}, SM Higgs, first collider dark matter
  - boosted top: Z'/KK resonances, 4th gen, vector-like quark partners

Why continue to do physics at the energy frontier?

What do we know now?

What do we know now?

1) there is a Higgs at ~126 GeV

What do we know now?

1) there is a Higgs at ~126 GeV

2) there is **not** a forest of new SUSY states or other new particles uncovered (yet)

What do we know now?

1) there is a Higgs at ~126 GeV

2) there is **not** a forest of new SUSY states or other new particles uncovered (yet)

3) there is dark matter

1) there is a Higgs at ~126 GeV

- low mass: LHC can measure its properties and couplings pretty well

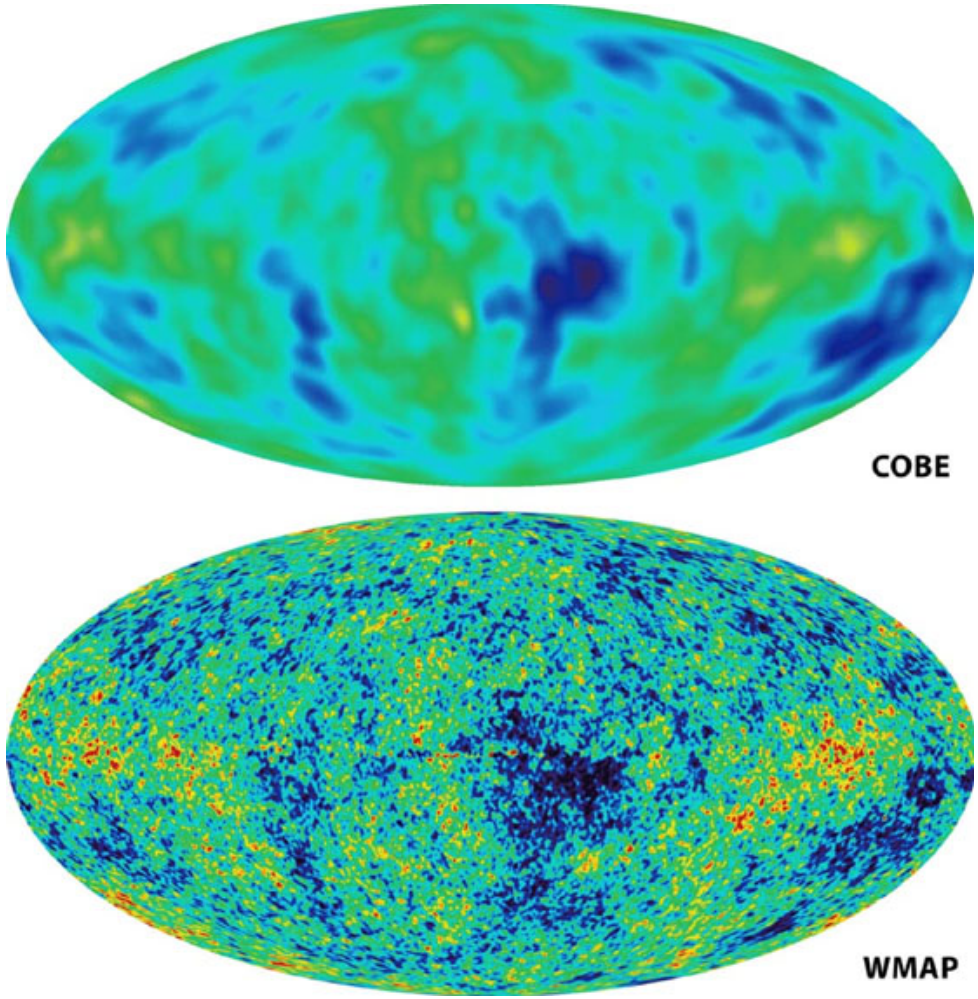
★ But absolutely need high luminosity LHC!

1) there is a Higgs at ~126 GeV

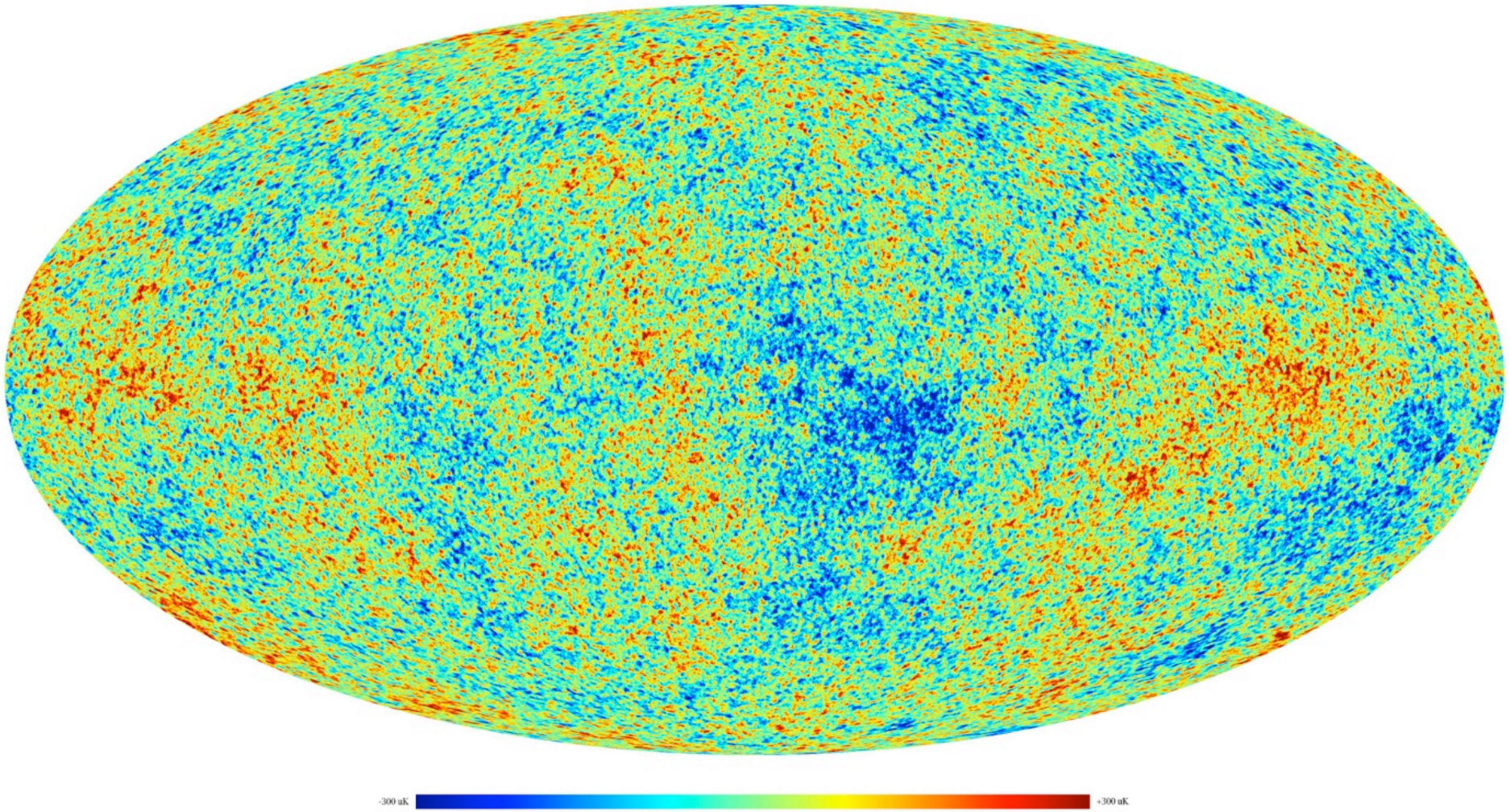
- low mass: LHC can measure its properties and couplings pretty well

  ★ But absolutely need high luminosity LHC!

- however, to really understand this Higgs and EWSB, need to probe couplings more precisely: lepton collider! (Is this true?)


COBE
WMAP

Planck!



1) there is a Higgs at ~126 GeV

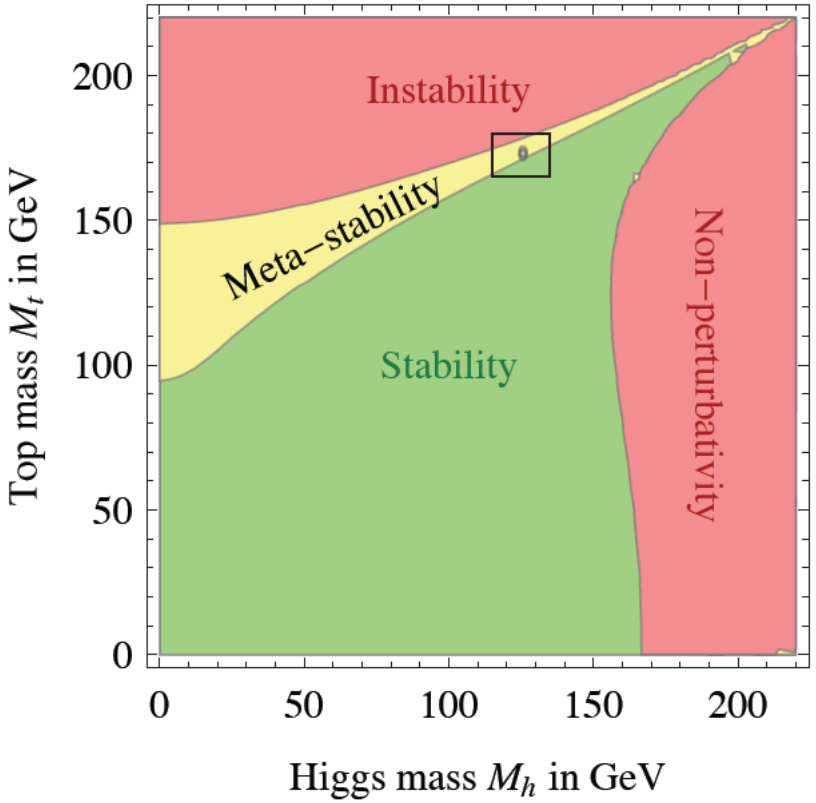
- low mass: LHC can measure its properties and couplings pretty well

  ★ But absolutely need high luminosity LHC!

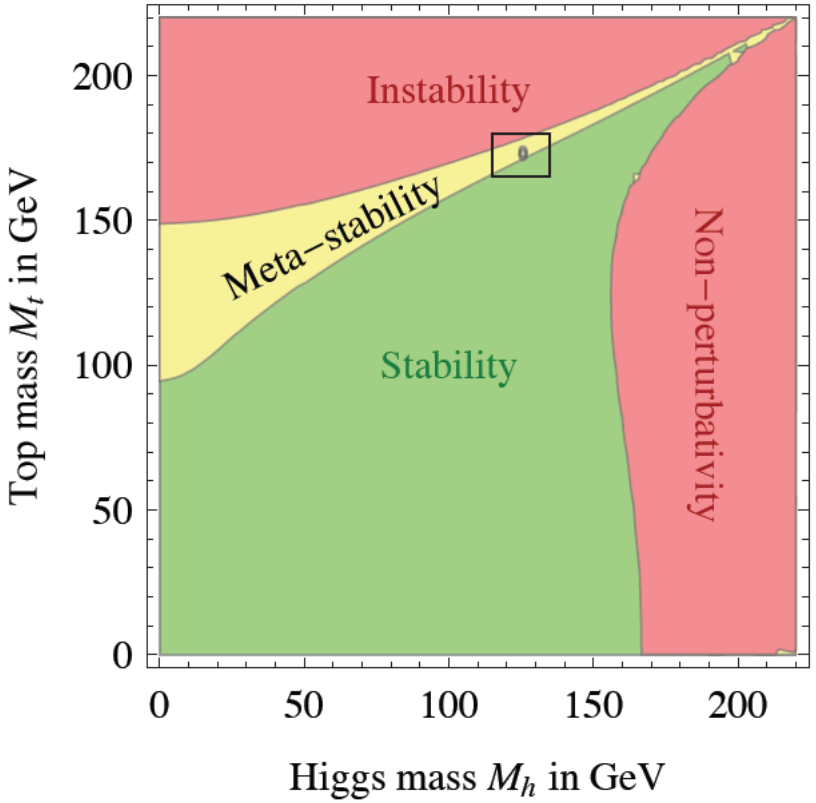
- however, to really understand this Higgs and EWSB, need to probe couplings more precisely: lepton collider!

- top + Higgs = meta-stable universe? (only if no new physics in intermediate scales)

meta-stable universe?



meta-stable universe?



Annie Hall

Mom: "Tell the doctor why you are depressed, Alvie."

Alvie: "Well the universe is everything, and if it is expanding, someday it will break apart and that will be the end of everything.

Mom: "You're here in Brookhaven. Brookhaven is not expanding!"

1) there is a Higgs at ~126 GeV

- low mass: LHC can measure its properties and couplings pretty well

  ★ But absolutely need high luminosity LHC!

- however, to really understand this Higgs and EWSB, need to probe couplings more precisely: lepton collider!

- top + Higgs = meta-stable universe? (only if no new physics in intermediate scales)

- still, we need more precise top mass (and top couplings) than EWK fits require

2) no SUSY forest or "primes" yet

- We still have a hierarchy problem to solve!

2) no SUSY forest or "primes" yet

- We still have a hierarchy problem to solve!
  - Precision Higgs studies may explain EWSB, but then what explains the Higgs?

2) no SUSY forest or "primes" yet

- We still have a hierarchy problem to solve!
  - Precision Higgs studies may explain EWSB, but then what explains the Higgs?
- We may begin to find things at 13 TeV

2) no SUSY forest or "primes" yet

- We still have a hierarchy problem to solve!
  - Precision Higgs studies may explain EWSB, but then what explains the Higgs?
- We may begin to find things at 13 TeV
  - SUSY? UED (PAMELA and AMS)? DM? Partners to stabilize Higgs mass?

2) no SUSY forest or "primes" yet

- We still have a hierarchy problem to solve!
  - Precision Higgs studies may explain EWSB, but then what explains the Higgs?
- We may begin to find things at 13 TeV
  - SUSY? UED (PAMELA and AMS)? DM? Partners to stabilize Higgs mass?
- If we don't find irregularities at 13 TeV:
  - We still have a hierarchy problem to solve!

2) no SUSY forest or "primes" yet

- If we don't find irregularities at 13 TeV:
  - We still have a hierarchy problem to solve!

2) no SUSY forest or "primes" yet

- If we don't find irregularities at 13 TeV:
  - We still have a hierarchy problem to solve!
  - There *is* a Higgs! So finding nothing doesn't mean there *isn't* anything, just that we haven't reached the right energy to see it, and/or not easy to find.

2) no SUSY forest or "primes" yet

- If we don't find irregularities at 13 TeV:
  - We still have a hierarchy problem to solve!
  - There *is* a Higgs! So finding nothing doesn't mean there *isn't* anything, just that we haven't reached the right energy to see it, and/or not easy to find.
  - New physics very likely within VLHC reach:
    eg: "warped models(a)" (arXiv: 1303.5056), eg: "simply unnatural SUSY(b)" (arXiv: 1212.6971), "unsplit SUSY(c)" (Dine et al), and... of course... there is dark matter!

(a) Soni, and references therein
(b) Arkani-Hamed, Gupta, Kaplan, Weiner, Zoraski
(c) work in progress, see Dine's intro talk

we're gonna need a bigger helicopter

3) there is dark matter

- we know there is dark matter, and a weakly interacting particle at a few hundred GeV fits nicely.

3) there is dark matter

- we know there is dark matter, and a weakly interacting particle at a few hundred GeV fits nicely.
- eg: SUSY solves dark matter and hierarchy problem.

3) there is dark matter

- we know there is dark matter, and a weakly interacting particle at a few hundred GeV fits nicely.
- eg: SUSY solves dark matter and hierarchy problem.
- until we produce and detect weakly interacting DM in the lab we won't understand what the right theory is.
  (if WIMP)

Why do we need the energy frontier?

Why do we need the energy frontier?

- discoveries we hope to make on the intensity frontier and on the cosmic frontier might mainly be indirect.

Why do we need the energy frontier?

- discoveries we hope to make on the intensity frontier and on the cosmic frontier might mainly be indirect.

- our goal at the energy frontier is nothing less than to produce and detect whatever new particles lie beyond the SM directly, and to explain EWSB and dark matter.

FIN

Thanks to Kaustubh Agashe and John Conway for their interesting discussions on these topics.

aside: Lepton collider

- linear or circular? question for Snowmass (or 13 TeV), but should allow for ttH
- right now my prejudice says should be scalable to at least ~few TeV
- should we build the design we have in-hand now? or try and build a two-fer? (2-for-1: lepton collider in a future circular pp tunnel)